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Investigation of particulate matters of the university classroom in Slovakia

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Abstract

University students spend most of their time in classrooms that do not always represent an ideal environment for education. This is mainly due to the fact that most university buildings in Slovakia are old. Classrooms can be contaminated by various indoor pollutants, such as allergens, particles, volatile organic compounds etc. Indoor air pollution can lead to long-term and short-term health problems for students and staff but also can lead to decreasing productivity. It is therefore essential to deal with the monitoring of indoor environmental quality in universities in Slovakia and propose realizable measures to improve this situation. The aim of this study is to investigate the particulate matters. The measurements were carried out in the university classroom during lessons. These measurements were repeated during to lessons carried out once a week for the duration of one month. Handheld 3016 IAQ - device was used for determination of particulate matter concentrations. Air temperature and relative humidity was set with multifunction device Testo 435-4. Questionnaire survey based on subjective perception of indoor environmental quality was also performed during this study. Students fill in these questionnaires at the beginning and at the end of lessons. Analysis was used for investigation of occurrence of PM concentrations and subjective evaluation of students.

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Keywords: particulate matter, indoor environmental quality, perceived air quality, classroom

1. Introduction

Indoor environment quality (IEQ) is considered as an indicator of the level of comfort which is not confined to the thermal conditions, it includes elements such as thermal comfort, acoustic comfort, indoor air quality and visual

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comfort [1]. Balancing energy performance and IEQ performance has become a conventional tradeoff in sustainable building design. In recognition of the impact IEQ performance has on the occupants of educational facilities, universities are increasingly interested in tracking the performance of their buildings [2]. Nearly zero emission or nearly zero energy buildings are main goals in various country roadmaps for 2020 [3]. Thanks to energy building certification, more Low energy buildings are being built with regard to this, we must point out that: a low energy building does not always correspond to high indoor comfort quality [4]. Exposure to particulate matters (PM) has been associated with higher rate of morbidity and mortality in urban areas and World Health Organization's International Agency for Research on Cancer (IARC) has classified PM component of air pollution as a carcinogen [5]. Pollution of the atmosphere continues to be a global concern for scientific research, environmental health and climate change. The control of air pollution over the past fifty years has seen the achievement of significant improvements in the quality of air, particularly in the urban environment [6]. Particulate matter is a key indicator of air pollution brought into the air by a variety of natural and human activities. As it can be suspended over long time and travel over long distances in the atmosphere, it can cause a wide range of diseases that lead to a significant reduction of human life. The size of particles has been directly linked to their potential for causing health problems. Small particles of concern include "inhalable coarse particles" with a diameter of 2.5 to 10 μm and "fine particles" smaller than 2.5 μm in diameter [7]. PM has well-known negative health effects on humans. PM exposure occurs mainly indoors because people spend most of their time inside buildings, especially in their homes [8]. Global climate change and increasing energy requirements have led to the development of energy-saving buildings typically characterized by low air-exchange rates. Given that people may spend more than 90% of their time in such enclosed spaces during the main activities of living, working and transportation, the investigation of indoor air quality (IAQ) in these micro-environments is of paramount importance [9]. High concentrations of air pollutants in ambient air may cause acute or chronic health effects, and even cause premature deaths in the elderly people and people with asthma; thus, the air quality forecasting studies became an important research topic for public health. A wide range of operational alert systems have been developed utilizing statistical and hybrid models, to take precautions before and during air pollution episodes [10]. Many studies deals with measure the indoor air quality in classroom. In study [11] was measure the indoor air quality in classrooms with special emphasis on particulate matter (PM_{10}) and carbon dioxide (CO_2) and the impact of cleaning and ventilation. Another study [12] reports particle mass and number concentrations and student exposure in classrooms in three secondary schools in Lublin, Poland, during the winter (February–March) and summer (May–June) season measurements. Research [13] was conducted at three selected schools in semiurban areas of Bandar Baru Bangi and Putrajaya, Malaysia to investigate the influence of the local surroundings on the IAQ in the school classrooms. The concentrations of gas pollutants (CO, CO_2) and particulate matter (PM_{10}, $PM_{2.5}$ and PM_1) have been determined using automatic portable indoor air spectrometers. The purpose of another study [14] was to measure and compare the indoor concentration levels of particulate matter ($PM_{2.5}$ and PM_{10}) in order to find out the spatial and seasonal variations across Gaza strip schools. Study [15] evaluated indoor PM concentrations on different microenvironments of three rural nursery schools and one urban nursery school, being the only study comparing urban and rural nursery schools considering the PM_1, $PM_{2.5}$ and PM_{10} fractions (measured continuously and in terms of mass). Outdoor $PM_{2.5}$ and PM_{10} were also obtained and I/O ratios have been determined. Passive sampling methodology was applied in another study [16] to collection of PM in classrooms of urban and rural primary schools. The samples were taken during a year by passive deposition allowing the study of seasonal variability of the particles masses and chemical content. Another study [17] presents an assessment of schools' indoor environmental quality, based on investigations carried out in three Italian classrooms in Treviso, in the North-East of Italy. Portugal study [18] presents an alternative approach using different ventilation systems. This system was applied in a part of a school building and the indoor environment was monitored during two months. Studies have been showing strong associations between exposures to indoor PM and health effects on children [15]. This study aimed at investigating the particulate matters in university classroom. The measurements were carried out in the university classroom during lessons and repeated once a week for the duration of one month. Subjective perception by questionnaire survey of indoor environmental quality was also performed during this study.

2. Materials and Methods

The objective of this study was to determine the level of particulate matter concentration and air temperature and relative humidity in university one classroom. Five measurements were carried out during the lessons in March. Indoor environmental quality monitoring was carried out in the university classroom, which is located in the 4th floor of building of Faculty of Civil Engineering. The teaching was attended by 10 students plus teacher. 60% of students were women with mean weight of 55.6 kg and mean height of 169.8 m, and 40% were men with mean weight of 82.8 kg and with mean height of 182.3 m. 90% from respondents are non-smoker. Average age of students was 24 years. The selected classroom had capacity up to 38 persons and volume of 191 m^3. The classroom was equipped with 19 desks from particleboard, 38 plastic chairs, blackboard for chalk, 8 computers, and one PC projector. In the classroom, there were 10 windows and 10 skylights, one door, lime plasters with water based paint on the walls, and flooring from OSB. All windows and doors have been open for 5 minutes before the lecture, and then they were closed and re-opened at the end of the lecture. No forced ventilation or air-conditioning system was used in the classroom. Measurement lasted 140 minutes. Concentrations of particulate matter were determined using HANDHELD 3016 laser particle counter. Air temperature and relative humidity were measured with multifunctional measuring device TESTO 435-4 with the IAQ probe. All measuring devices were placed in the centre of the classroom in the height of 1.1 m above the floor. Questionnaire survey was carried out in the classroom for the purpose of evaluation the influence of indoor environmental parameters on students, except the monitoring of IEQ parameters. The questionnaires were completed only by students at the beginning and the end of the lecture, but teacher was also present in the classroom during measurement. Different types of evaluation scales were used in the questionnaires. There were used scales of perception, scales of sensational evaluation (Fig. 1 a, b; Fig. 2 a), and overall evaluation for indoor environment (Fig. 2 b) [19].

a) b)

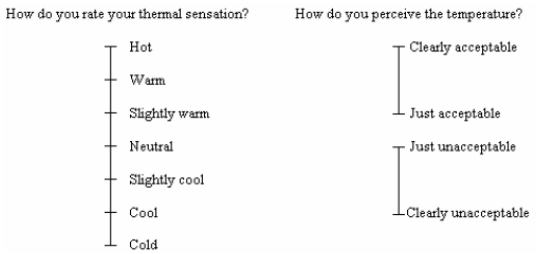

Fig. 1. (a) Thermal sensation; (b) Perceived temperature

a) b)

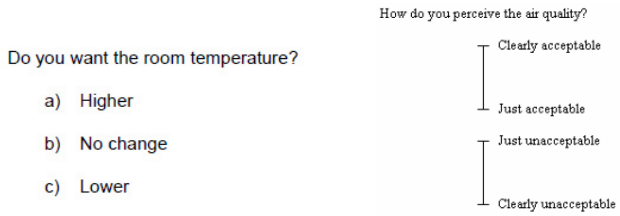

Fig. 2. (a) Temperature; (b) Perceived air quality

3. Results

3.1. Objective measurement

The minimum and maximum air temperature and humidity measured in classroom are shown in the table (Table 1). The minimum temperature of 21°C (23.3.2016), maximum of 26.5°C (2.3.2016) and mean value of 23.99°C. The minimum air humidity in classroom ranged from 27.1 % (23.3.2016) to 38.1% (9.3.2016) with mean value of 32.57 %.

Table 1. Temperature and relative humidity

Date	2.3.2016		9.3.2016		16.3.2016		23.3.2016		30.3.2016		Average		
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Mean
Temperature [°C]	22.9	26.5	22.9	25.7	22.4	25.6	21	26.4	22.4	25.5	21	26.5	24.13
Relative humidity [%]	30.7	38.1	33.3	38.1	27.5	35.4	27.1	34	30.8	33.8	27.1	38.1	32.88

Table 2. Mean values of particulate mass concentrations

Day	0.3μm dif PM m^3	0.5μm dif PM m^3	1.0μm dif PM m^3	2.5μm dif PM m^3	5.0μm dif PM m^3	10.0μm dif PM m^3	Total PM m^3
2.3.2016	0.00	6.21	9.51	13.15	37.06	71.65	95.30
9.3.2016	0.00	4.97	7.08	9.81	29.54	64.26	89.08
16.3.2016	0.00	4.64	6.53	11.10	43.02	81.73	108.04
23.3.2016	0.00	6.38	9.56	14.43	49.84	95.50	121.32
30.3.2016	0.00	4.35	7.40	12.58	43.30	90.03	134.33
Min	0.00	4.35	6.53	9.81	29.54	64.26	89.08
Max	0.00	6.38	9.56	14.43	49.84	95.50	134.33
Mean	0.00	5.31	8.02	12.21	40.55	80.63	109.61

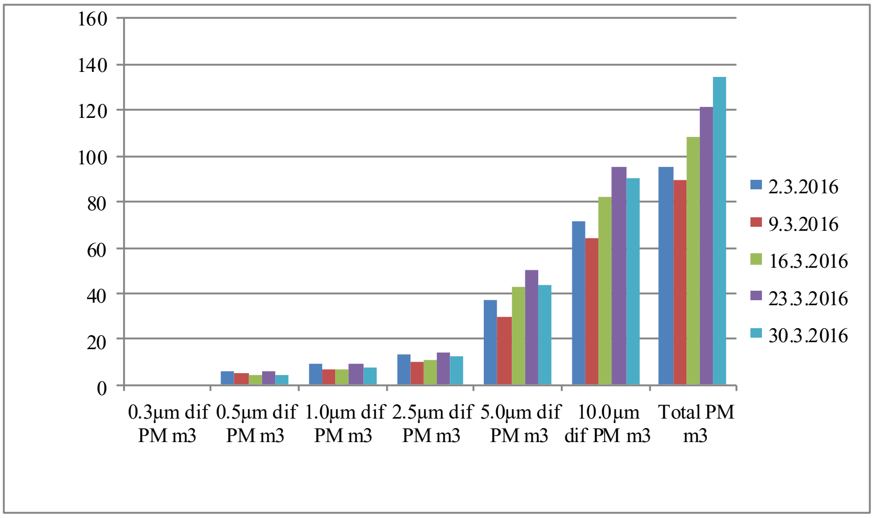

Fig. 3. Comparison of particulate mass concentrations.

Total PM concentrations presented as measured particles without size fraction selection differed widely and ranged from 89.08 to 134.33 μg.m^{-3} in the monitored university classroom with an average value of 109.61 μg.m^{-3}. PM_{10} concentrations ranged from 64.26.0 to 95.5.4 μg.m^{-3}. The measured PM_{10} values were compared with the maximum value according to Slovak legislation (Decree of the Ministry of Health of the Slovak Republic No. 259/2008) [20]. The maximum permissible value for PM_{10} indoor concentration (50 μg.m^{-3}) was exceeded in each of measurements. The calculated average value of PM_{10} in the offices (80.63 μg.m^{-3}) was also found to be higher than the permissible limit. Comparison of the PM concentrations measured in the monitored classroom of the present study is illustrated in Figure 2. Values of mean mass concentrations of particulate matters for each measured fraction ($PM_{0.3\text{-}0.5}$, $PM_{1.0\text{-}2.5}$, $PM_{2.5\text{-}5.0}$, $PM_{5.0\text{-}10.0}$) in classroom are presented in the Figures 4-7.

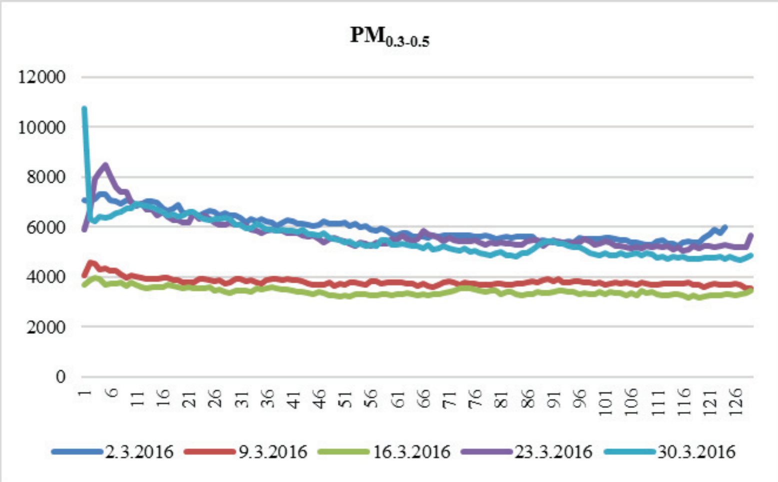

Fig. 4. Course of particulate number concentration of $PM_{0.3\text{-}0.5}$.

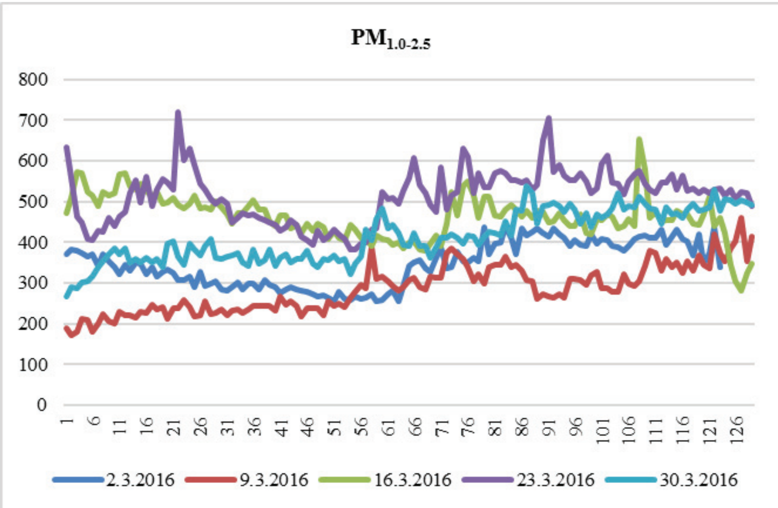

Fig. 5. Course of particulate number concentration of $PM_{1.0\text{-}2.5}$.

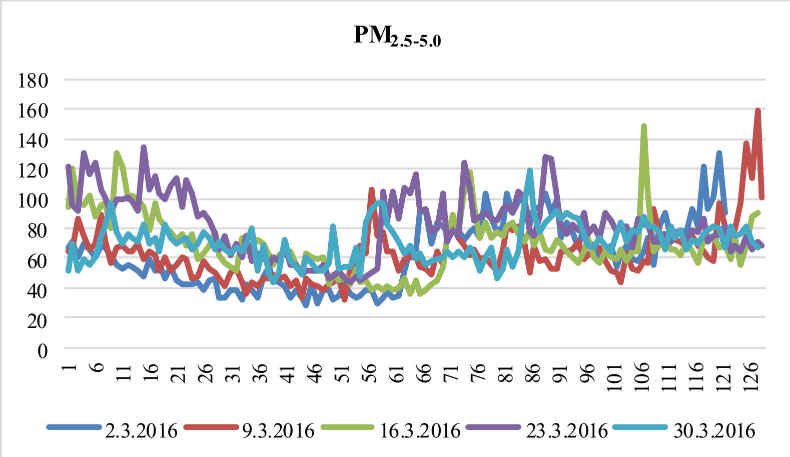

Fig. 6 Course of particulate number concentration of $PM_{2.5\text{-}5.0}$.

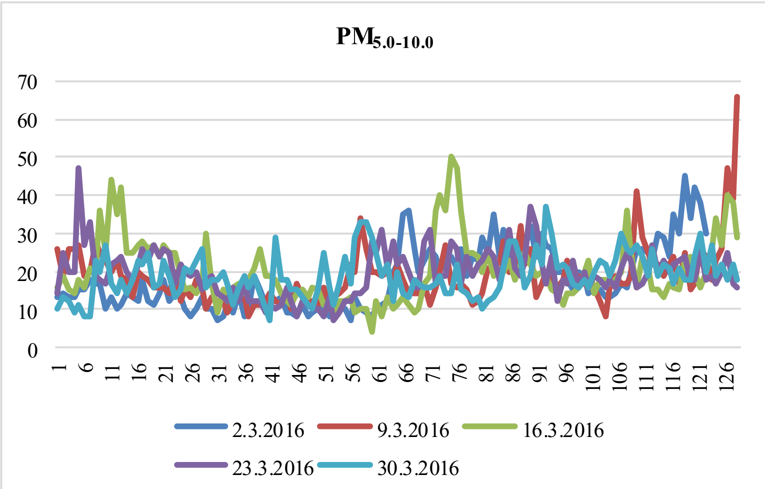

Fig. 7 Course of particulate number concentration of $PM_{5.0\text{-}10.0}$.

3.2. Subjective measurement

Results of questionnaire survey correspond to objective measurements in the classroom during to lessons carried out once a week for the duration of one month. Student's evaluated of indoor environmental quality parameters was worse at the end of the lecture as at the beginning. In average, students evaluated temperature as slight heat, humidity as neutral. Students marked the indoor environment as more acceptable than unacceptable and well tolerable in general. In the table (Table 3) is shown result from subjective evaluation on IEQ parameters. In average, 52% of student rated air temperate as comfort and 28% as slight discomfort at the beginning of the lecture. On the other hand, 30.5% of students rated air temperature as comfort, 64.2% as slight discomfort, and 5.3% as discomfort at the end of lecture. 94.7% of students evaluated level of humidity as comfort, 2.5% as slight discomfort and 2.8% as discomfort at the beginning of lecture, and 67.6% as comfort and 32.4% as slight discomfort at the end of lecture.

These results correspond to objective measurements in the classroom. Students marked the indoor environment as more acceptable than unacceptable and well tolerable in general.

Table 3. Result from subjective evaluation of IEQ parameters

Parameter		2.3.2016	9.3.2016	16.3.2016	23.3.2016	30.3.2016	Mean
	the beginning	0.7	1.1	0.5	0.89	0.8	0.798
Temperature	the end	1.4	1.3	1.1	1.22	1.2	1.244
	the beginning	0.2	0.1	0.1	0	0	0
Humidity	the end	0.3	0	0.1	0	0	0
	the beginning	0.5	0.14	0.25	0.44	0.8	0.426
IEQ	the end	0.7	0.57	0.88	0.89	0.4	0.688

4. Discussion

Particles are produced by photochemical atmospheric reactions and the coagulation of combustion products from automobiles and stationary sources, with lifetimes of several days or more. The occurrence of particulate matters indoors depends on outdoor pollution and its transport indoors as well as on the presence of indoor sources [21]. Our previous study [22] were investigated in terms of the particulate matter occurrence in selected office room. Both mass and number concentrations have been measured with the result: much higher mass concentrations have been observed in room 2 (out of operation) when compared to room 1 (operational mode) for all size fractions; the ratio of mass concentrations for room 2/room 1 ranged from 1.15 for PM_{10} to 2.45 for $PM_{0.5}$; PM_{10} concentrations of particulate matters measured in office rooms (27.9 and 32.2 $\mu g.m^{-3}$) did not exceed the Slovak limit value for indoor air (50 $\mu g.m^{-3}$). Another previous study [23] was focused at investigation of indoor environmental quality, performance and comfort of employers in selected office building. Study was conducted during the heating and non-heating season. Occupants were requested to evaluate their subjective and objective performance. The average overall performance of users in the heating season was 84.4% and in the non-heating season was 98.3%.

The measured PM_{10} values in our study were compared with the maximum value according to Slovak legislation that lead the maximum permissible value for PM_{10} indoor concentration (50 $\mu g.m^{-3}$). This permissible value was exceeded in each of measurements. Measurement of particulate matter concentrations were also performed in study [14]. In this study were co carried out using hand held particulate matter instrument during fall, winter and spring seasons from October 2011 to May 2012 inside and outside the classrooms of twelve naturally ventilated schools located in Gaza strip, Palestine. The average concentration of indoor PM_{10} was 349.49 (+/-196.57) mg/m^3 and for $PM_{2.5}$ was 103.96 (+/-84.96) mg/m^3. Another study was oriented to measure the indoor air quality in classrooms with special emphasis on particulate matter (PM_{10}) and the impact of cleaning and ventilation with the result: levels of PM_{10} in the classrooms during the 3 weeks were 69719 mg/m^3 and they were dominated by occupancy and the persons' activity. Intensified cleaning showed a significant decrease in all classrooms (79722 to 64715 mg/m^3). The effect of ventilation on levels of PM_{10} was inconsistent. Result of study from [13] show that the overall average concentrations of the main parameters recorded inside the schools were 31 mg/m^3 (PM_{10}), 18 mg/m_3 ($PM_{2.5}$) and 16 mg /m3 (PM_1). These concentrations were below the recommended values suggested in Malaysia.

5. Conclusion

Monitoring of classroom in our study during to lessons shows that PM mass concentrations ranged widely based on particle size: 64.26-95.50 $\mu g/m^3$, 29.54-49.84 $\mu g/m^3$, 9.81-14.43 $\mu g/m^3$, 4.35-6.38 $\mu g/m^3$, 0 $\mu g.m^{-3}$ for PM_{10}, PM_5, $PM_{2.5}$, PM_1, and $PM_{0.5}$, respectively. The permissible value for PM_{10} indoor concentration (50 $\mu g/m^3$) was exceeded in 100 % of measurements. Results of objective measurement correspond to subjective measurements in the classroom. Students marked the indoor environment as more acceptable than unacceptable and well tolerable in general. Increased levels of PM_{10} concentrations measured indoor as well outdoor resulted in heating of houses with solid fuel. Use of renewable energy sources seems a better alternative in terms of air pollution especially in the heating season. Reducing the concentrations of particulates in the air during the possible construction works which can potentially increase the concentration it would be achieved by sprinkling the transported building materials and components or their covering with a sheet.

The future work will be aimed on monitoring a statistically significant set of selected university classrooms, determination of indoor PM occurrence depending on the surrounding environment, identification of indoor sources of PM and determination of correlation between subjective perception and measured PM concentration.

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